



OUTLINES
OF THE
ORIGIN AND PROGRESS
OF
GALVANISM;
WITH ITS APPLICATION TO
MEDICINE.

IN A LETTER TO A FRIEND.

——
BY WILLIAM MEADE, M.D.
——

PRINTED BY J. CONNOR,
FOR A. ARCHER,
DUBLIN.

——
1805.

For
Mr Russell

with best respects

from the

Author

TO
ROBERT PERCIVAL, M. D.

Professor of Chemistry in the University of Dublin,

WHOSE TALENTS AS A PHILOSOPHER,

AND

JUDGMENT AS A PHYSICIAN,

ARE ONLY EQUALLED

BY THE ZEAL WITH WHICH HE PRACTICES,

AND THE

ARDOR WITH WHICH HE PROMOTES

THE PRINCIPLES

OF

RELIGION AND *VIRTUE*,

THESE OUTLINES

OF THE

SCIENCE OF GALVANISM,

AS CONNECTED WITH MEDICINE,

ARE MOST RESPECTFULLY INSCRIBED

BY

THE AUTHOR.

THE JOURNAL OF

JOHN W. FULTON

1840-1841

Vol. I

Part I

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PREFACE

TO THE SECOND EDITION.

THE favorable manner which my first attempt has been received, has induced me to comply with the request of my BOOKSELLER, and to give to the PUBLIC a new and enlarged Edition of the Origin and Progress of GALVANISM—when I first ventured to state my ideas on this subject, the Science was only in its infancy,—no systematic Treatise having appeared on it; those who wished to derive information on this interesting subject could only obtain it in detached Essays, published in periodical Papers, particularly in Nicholson's excellent Journal; these, however, fell into the hands of but few persons, and the Public in general, were at that time scarcely acquainted with the name of Galvanism. This will plead my excuse, for attempting so early to diffuse a more general knowledge of it. Since that period, however, others who were engaged with the
same

same zeal, have published very full and distinct information on it, and the Science, though it has not made the same progress that was to be expected, yet it still has been much improved; and considerable light has been thrown on many of its most important phenomena.

Further observation and experience has also enabled me to make some improvements in the construction of the Galvanic Apparatus; and many new facts have occurred since the publication of the last Edition of this Treatise, which I have now particularly noticed, but in no part of the Science has more information been obtained, than in that which is connected with its application to Medicine; here a new field has been opened for the practical Physician, such as eminently entitle it to the attention of the Profession.

I have, therefore, now collected whatever has been lately noticed with respect to it, and have considerably enlarged that part of this Treatise with the result of my own experience, as well as that of others; hoping, thereby to add in some degree, an increased confidence in this remedy, for the removal or alleviation of some of the most dangerous Diseases to which the human frame is liable. Should any advantage arise to my Brethren of the Profession, from the observations which I have here collected, I hope it will plead some excuse for thus intruding a second Edition on the Public.

DEAR SIR,

WHEN I had lately the honour of seeing you, our conversation naturally turned on a subject which has for some time engrossed the attention of all philosophers, and indeed could not but materially interest the minds of men of science, who were occupied in the pursuit of useful knowledge. You will be at no loss at present to perceive that I allude to the late extraordinary discoveries in Galvanism, or what is frequently called Animal Electricity. The experiments which have been made on this subject have led to conclusions so curious and important, that I feel no surprise at your anxiety to be acquainted with the origin and progress of the science of Galvanism. To a mind so capacious as your's, and so intimately acquainted with Chemistry, and every other branch of useful knowledge, the detail which it will be necessary for me to undertake may appear tedious and superfluous; but give me leave, Sir,
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here to observe to you, that the sciences of Chemistry and Natural Philosophy are but little attended to in this country; men of talents and of education are but seldom accustomed to such conversation, living, as it were, out of the philosophical world, they feel unacquainted with those facts, which are not only valuable simply as they are connected with the sciences, but as they relate to the improvement of many of the processes and operations in common life.

Should I, therefore, appear to you either too prolix or diffuse in these observations, I beg that you will recollect, that my object is to inform those who have little leisure to read elaborate treatises, and but few opportunities of receiving much information from the works of modern authors.

The numerous and various occupations of your own life, prohibit you from paying that attention to our present subject, which, otherwise, your ardent and philosophic mind would eagerly embrace.—Some leisure hours, with the opportunity afforded me of an acquaintance with men of science in England, have induced me to devote much of my
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attention to the subject of the following pages. I claim little merit either in the design or compilation; but, should it save you the trouble of perusing the numerous and uninteresting works which are to be found on Galvanism; or tend to encourage in others a taste for the study of Chemistry, with which this subject is so intimately connected, and to guide inquisitive minds in their researches after curious and instructive knowledge, I shall esteem my labour sufficiently rewarded: at the same time I may presume that a work, which has for its object to give a concise and general view of the origin and progress of Galvanism, may not be totally unacceptable to the generality of readers.

ON THE
ORIGIN OF GALVANISM.

DISCOVERIES in most of the sciences, however improperly named, are generally distinguished after the name of the person who had the first claim to the discovery; this, among the rest, has obtained its present title from the celebrated Galvani, Professor at Bologna, who, accidentally amusing himself with some electrical experiments, observed some of those properties of metals which have since led to so many important discoveries. He first perceived, while dissecting a frog, that by touching a nerve of the animal, when sparks were taken from the conductor of an electrical machine, its whole body was agitated by violent commotions; this led him to make many experiments on the subject, and he soon found that these convulsions could be produced without the aid of electricity, merely by touching the nerves of the animal with two different metals, which at the same time touched each other; or communicated by the intervention of any substance capable of conducting electricity.

This simple experiment may be tried to convince any person of the fact: lay bare the nerve of an animal, touch it with a piece of zinc, and any part of the limb with a silver probe, then bring the
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other ends of the two metals into contact, when violent contractions will be produced in the muscle. It has also been found, that the limbs or muscles of many animals continue capable of excitement for several days after death.

Frogs, unfortunately for them, from their great vitality, have generally become the victim of those experiments; which any person may easily try, in the following manner: lay bare the sciatic nerve of a prepared frog, touch this with a silver probe, while the muscles of the lower extremities are touched with a piece of zinc, then bring the ends of these metals into contact, when violent convulsions will be produced in the animal; or lay the prepared nerve on a shilling, while the feet are placed on a plate of zinc, complete the circuit by any conducting substance, and the same effect will instantly be produced, which are repeated as often as the contact is made.

Most metals when applied in this manner will shew some effect, but the most powerful certainly are zinc, tin, or lead, when used in conjunction with gold, silver, or copper. The process is simple, nothing more being necessary to excite those movements than the formation of a circle, of which part should be the muscle acted on, and the whole circle completed by the metals. By varying the application of these metals, in this way with different parts

of the body, many curious and entertaining experiments may be performed.

For instance: If a rod of zinc be applied to the upper, and another to the under surface of the tongue, and these two metals then brought into contact, a very peculiar sensation suddenly takes place, resembling a very slight electrical shock, and accompanied with such a subacid taste in the mouth as is difficult to describe.

Secondly, If a piece of zinc be placed high up between the upper lip and gum, (or, what frequently succeeds better, thrust far up the nostrils,) and a silver rod be introduced under the tongue, as soon as the other ends of those rods are brought into contact a very vivid sensation is perceived, and a sensible flash of light appears before the eyes.

Thirdly, Place a plate of silver on a table, and over this a plate of zinc, somewhat less in diameter, so as to leave part of the silver edge appear all round, then on this plate of zinc lay a leech, or a small worm; when the insect attempts to move off the zinc, he receives such a shock on touching the silver, as to induce him to return, and having tried it in different points, with the same success, he generally gives up the point, and quietly submits to his imprisonment.

Fourthly,

Fourthly, Place a silver cup on a plate of zinc, fill this cup with pure water, taste the water in this state, no perceptible effect is produced, but wet your hand and touch the zinc plate with it, then apply your tongue to the water, and a very sensible change occurs, a pungent sensation is produced and the water tastes sensibly acid. This simple experiment serves to explain many curious phenomena: such as the different taste which is perceived in porter when drank out of a pewter vessel. Indeed this refinement is carried so far, that professor Robinson asserts, that the flavour of snuff is much more pungent when taken out of a box, which has been coated with tin foil. However extended this opinion may be, it is certain that the taste is considerably influenced by the combination of metals, and that many circumstances observed in common life are easily accounted for on Galvanic principles. So sensibly is the taste affected, either by an alloy, which is a combination of two metals, or by any metal when in contact with another, that a nice observer can tell even where a metal has been soldered, by examining it with his tongue, the sense of taste being immediately affected when the tongue passes over the soldered part, which is otherwise not to be perceived.

I shall not, Sir, waste your valuable time by a further detail of those trifling experiments; they were the natural results of the first discovery made

by Galvani, and the science continued for several years but little improved, till the very extraordinary discovery of the vast accumulation of the Galvanic influence, which was made by Volta early in the year 1800. Its powers were so remarkable, and the effects so curious, as to rouse the attention of all Philosophers; and from this only may be dated the first improvements, which can be considered interesting in Chemistry, or useful in medicine.

ON THE
PILE OF VOLTA.

FOR more particular information relative to this part of the subject, I must refer you to a very elegant paper in Nicolson's Journal, Vol. i. p. 179. It will be necessary, however, for me to state the leading facts, and to describe minutely the apparatus which Volta made use of, and also the improvements which have since been made in it.

Volta's first attempt was to encrease the Galvanic influence, by adding to the number of pieces of metal; and having first placed on a table a flat piece of silver, then a piece of zinc of the same dimensions, he found that in order to produce any Galvanic effect, it was necessary before the pile was further encreased, to interpose a fluid, capable of acting in some degree on one of the metals; he then added a piece of paper or pasteboard, well soaked with a solution of common salt, or muriatic ammonia, and by continuing to encrease the pile, first silver, then zinc, next moistened paper, then silver again in the same succession, he found that a pile constructed in this manner afforded a perpetual current of what he called the electric fluid, which was capable of exciting violent muscular action; by touching it with the hand, or any conductor,

conductor, at the upper and lower plate, and that these shocks are repeated as often as the hand is applied. This is what is called a simple Galvanic combination, and when two metals are employed, the greatest effect is produced when one is easily oxydated, and the other is not acted on. Thus gold and zinc are the most powerful, because gold is a metal of most difficult oxydation, and zinc on the contrary, is easily acted on by any acid. The pile formed in this manner, may be called a battery, the strength of which is considerably encreased by the kind of metal employed, and the shock which it gives is in proportion to the number of plates employed, more than to their size. It resembles so much the effect produced by the Leyden vial, that it is not surprising that philosophers should at once call this electrical, and attribute it entirely to the electric fluid; but those who have been accustomed to the frequent application of the electric and Galvanic shock, perceive a very marked difference in its effects on the whole nervous system; it is not so instantaneous, and gives a much more continued and tremulous sensation; and we shall hereafter see that many philosophers at present, are disposed to attribute it to other causes.

In the management of the pile many circumstances are to be attended to; the intensity of Galvanism is so low that it cannot make its way through the dry skin; to produce, therefore, the
strongest

strongest effect, it is necessary that the hands should be completely wet, and a large piece of metal grasped in each hand, with the points of which the pile may be touched at each end. Or, place a plate of metal under the first plate of silver, and another over the upper plate of zinc, let the ends of these communicate with two different cups of water, into which the hands may be plunged, and by this means, the circle being complete, the shock will be received. However, discharging rods, such as I have given in the plate, are more convenient, and can be used to receive shocks of any intensity by touching different points of the pile.— But what is singularly curious in the pile constructed in this manner, is the spark which can be procured by touching the points of two conductors communicating with each end of the pile; this spark appears to me essentially different from the electric, it is much more bright and vivid; it will sometimes appear three or four times together, but at other times the contact may be frequently made without any sign of it, though attended with the same circumstances, which is rather unaccountable; and I have frequently observed a bright flash follow the spark and shoot along the conductor; it always appears on the wire connected with the silver side, which would give out hydrogen; and may be exhibited before the eyes at any time in a very singular manner. Place a wire in the mouth, which communicates with one end of the pile, and complete the

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the circuit by touching with a wet hand the wire which communicates with the other. The flash in this manner appears to encircle the face, and a sharp pungent taste is produced in the mouth.

The spark can be procured much easier and more luminous by connecting a small piece of charcoal to the point of one of the wires, and if the machine is of proper strength the charcoal may even be ignited, or it may be seen under water by connecting the wires in the same manner. It will also be obtained with greater facility, if one of the wires terminate in a fine point while the other is round. This gave rise to a number of attempts to ignite metals with the Galvanic pile, some of which are detailed in a Report to the National Institute at Paris, by Fourcroy, who succeeded completely in igniting different metals; and if this is done in oxygen gas, a real deflagration and decripitation will take place; but for this purpose, he says, that it requires plates of nine or ten inches square, eight or ten of which will be sufficient, while those plates scarcely give any shock, and are by no means powerful in the decomposition of water.

Nothing can be more interesting than the powers of Galvanism in igniting and deflagrating metals; in this as well as in many other points it differs essentially from electricity. I am aware that a powerful charge of an electric battery will deflagrate a
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considerable portion of any metallic substance ; but this is done in an instant, the metal is generally dissipated, nor can it be kept in a state of ignition. In attempts of this kind on a large scale, with a Galvanic apparatus, I have seen thirty inches of iron wire, not only fused, but exhibited before the eyes for a considerable time, in a red heat, as frequent as the communication is made. Its powers also in producing light, differ from electricity.—When plates of large dimensions are made use of, an intensity of light is produced little inferior to solar light, and such as that the eye can scarcely behold it without pain, greatly superior to what has ever been produced by experimental philosophy, or chemistry. This, unlike the electric spark, can be exhibited like a fixed star, by bringing the ends of two wires together which are armed with good charcoal, but it is always necessary that the parts should be in actual contact, nor can the smallest effect be produced in Galvanism, unless this is the case. In this one circumstance alone, perhaps, does Galvanism differ from electricity more than any other ; in the latter neither a continued light nor a continued heat can be kept up ; while in the former we have both at our command, and can let them gradually loose, or in a continued stream, at pleasure, but at all times requiring actual contact.

Thus far merely had Volta and other continental philosophers gone, when Messrs. Nicolson and Car-

liffe undertook to repeat these experiments, and to them principally are we indebted for the discovery of the powerful effects of Galvanism, as a chymical agent, particularly in its action on metals, and in decomposing water. Accident here, as well as in the first experiments of Galvani, led to this curious discovery.

While engaged in repeating the experiments of Volta, Messrs. Nicholson and Carlisle observed bubbles of air to arise from the points of the conductors, whenever they came in contact with water; this suggested the idea of examining the nature and origin of this aireform fluid.

The results of their enquiries are as follow— that the Galvanic pile has the power of decomposing water and oxydating metals. Some improvements have been since made in the apparatus for this purpose, which I shall detail, referring you for a more particular account to Nicholson's * Chemical Journal.

It was necessary, in order to collect the gas arising from the pile, to contrive a method of receiving it; the first attempt was by such a tube as may be seen in the plate given by him. Let this tube be filled with water, and each end closely stopped with a cork, in which a gold wire is introduced, so as to meet

meet within half an inch of each other, connect then each end of the wire with the pile. so as to complete the circuit, immediately gas will be seen to arise from the points of both wires, so as to collect in considerable quantity in the tube; which gas, when examined, was found to contain two parts hydrogen, and one part oxygen; these, when fired together, either by a taper or the electric spark, will explode and form water.

They may also be fired by the Galvanic spark, as both Messrs. Bolton and Crookshanks have ascertained; but, in order to collect those gases separately, other tubes were constructed, as in plate, fig. 1st. by which means it was ascertained, that the gas arising from the silver side was hydrogen, while that from the zinc was oxygen, and as nearly as possible in the proportion stated to be the component parts of water.

To procure these gases the points of the wires should not be more than half an inch asunder, if they are much farther no decomposition takes place. This is invariably the case, which ever way you turn the pile, and has suggested the trial of different metallic wires, by which means other curious circumstances have appeared.

For instance, connect a gold wire with the zinc end of the pile, and a brass wire with the silver end, the

result will be the same as if both wires were gold, viz. oxygen arising from the zinc side, and hydrogen from the silver; but reverse the pile and a very striking circumstance appears: no gas arises from the brass wire connected with the zinc side, but it immediately changes its colour, blue clouds encircle the point of it, and a very rapid oxydation of the metal immediately takes place, while hydrogen continues to arise as before from the gold wire connected with the silver side. The cause of this is sufficiently obvious; the oxygen fixing itself in combination with this brass wire; but if it had been gold or platina, metals of difficult oxydation, then oxygen, instead of being fixed in it, would have been extricated as in the first experiment. All metals, therefore, which are acted on by acids, or easily combine with oxygen, are unfit to be used for the decomposition of water, when connected, as in this experiment, to the zinc side of the pile:

Salmon has examined those combinations, and made many experiments with different wires, on what he calls the Galvanic Acid, or the power which the pile has in oxydating metals, and reducing them to a saline state; such particularly as zinc, copper, silver, and iron. I have repeated these experiments, but not exactly with the same result.— These metals have invariably been oxydated when connected with the zinc side, the oxydes of which were of different colours, according to the metal employed;

ployed; but I never have obtained those brilliant crystals which he describes.

In following up those experiments, it was natural to try the effect of passing the Galvanic current by means of wires, through other fluids and different metallic solutions. When Ammonia is exposed to its action instead of water, a very rapid decomposition of it takes place, its state of aggregation being more weak than other fluids, Hydrogen and Azote are the result of the process;—and by passing repeated electric sparks through these gases, Ammonia may even be reproduced: but if in this case we use silver wires, no decomposition takes place, fulminating silver being formed on the silver wire connected with the zinc side of the pile, which will detonate violently by even the smallest friction; this was accidentally discovered by Crookshank, and if the experiment is attempted on a large scale the effect of the detonation may be attended with unpleasant consequences.

Spirit of Wine has also been submitted to the action of Galvanism, the spirit is in this case also decomposed, but not without the wires are armed with good charcoal, and in contact; brilliant sparks are then produced, and carbonic acid gas, and hydrocarbonate are the result of the process. When wires armed with charcoal are introduced into water, the same brilliant sparks appear, but no heat

is produced though the light is very evident ; which shews that light is not always the consequence of heat, and that they may exist separately.

It has been ascertained that oxygen and hydrogen are never obtained but when pure water is used. When this water is coloured by Tincture of Litmus, it is changed to a red colour, as far as the point of the oxydating wire, (that is always to be understood the wire connected with the zinc side) while the other part remained blue. Hence it appears that the oxygen had combined with the Litmus, so as to produce the effect of an acid.

If the tube filled with distilled water and tinged with tincture of Brazil wood, be submitted to the Galvanic influence in the same manner, the fluid which furrounds the wire connected with the silver side, becomes a deep purple. This is as deep a colour as can be procured by Ammonia, and evidently shews that an alkali is, in some manner produced by the hydrogen arising at this side.

When the Galvanic influence is passed through metallic solutions in acids, the constant effect appears to be the revival of the metal held in solution ; this revival is produced by the hydrogen gas, which is known to reduce the oxydes of metals. The solutions which have been submitted to this experiment are, acetite of lead, sulphate of iron

iron and copper, and nitrate of silver, and on those occasions bright metallic precipitations were always produced by the hydrogen; but particularly from the nitrate of silver, shoot fine needle-wire like crystals, beautifully formed like the *Arbor Dianæ*. In all those cases no hydrogen gas is disengaged, it fixing itself in combination with the metallic precipitate.

From those experiments it has been suggested by Mr. Crookshank, that Galvanism may be employed with success in the analysis of minerals. That it may be a useful chemical agent there can be no doubt; we have seen that different metals can be distinguished by the action of Galvanism, when connected with the zinc or oxygen side of the trough, and it is evident that the nature of any metallic solution may be ascertained, by submitting it to a current of gas arising from the silver or hydrogen side of it. I have myself found it a very useful test of the presence of iron in a chalybeate water, and I have no doubt but further experience will enable us to convert this science to the elucidation of many of the important works of Nature.

These are a few of the numerous interesting experiments, which the pile of Volta has given rise to, they are not only highly amusing to the curious observer, but they appear to open a new field of investigation to the scientific Chemist. It is, perhaps, unnecessary to add a variety of other circumstances
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connected with this subject; enough has been said to shew to how many useful purposes this discovery may be applied. Philosophers have occupied much of their attention in endeavouring to illustrate the causes of these phenomena; little, it is true, has yet been done to explain them in a proper manner;—however, I shall, in the next chapter, take a slight view of the different theories which have been suggested on this subject.

ON THE
THEORY OF GALVANISM.

I SHALL not here enter deeply into the investigation of the different theories which have been suggested to account for the phenomena of Galvanism. Those who were at first disposed to attribute all these to an electrical cause, now see so many objections to this explanation as to hesitate in their former opinion. That the pile shews some of the qualities of electricity is evident, from its effects on the electrometer; and it has been said by Mr. Crookshanks, that he could charge a Leyden vial so as to give a small shock, by placing the pile between the coatings; many others have, however, attempted this without success.

An anonymous correspondent, in Nicolson's Journal,* says, that after a variety of trials, he has succeeded in charging a jar, so as to produce a slight shock, or rather taste in the mouth, by filling the jar, nearly with salt water, and placing it in a vessel containing the same fluid, as nearly as possible to the same height, he then connected the inside of the vial with one end of the pile, and the outside

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* Vol. v. p. 174.

with the other; by this means imitating, in some degree, the coating of the Leyden vial.

Since this, however, Van Marum,* of Haerlem, has succeeded in charging a battery with the pile, and has gone farther than any other person to prove the identity of Galvanism and the electric fluid. But notwithstanding this, from a variety of other circumstances, such as the different sensation produced by the shock, the necessity of the hands being wet to receive it, and its producing no report; the appearance both of the flash and the spark, and the trifling appearance of other electrical phenomena, it is not surprising that philosophers should doubt its being entirely an electric phenomenon; or, seeing some signs of electricity, should attribute it, in part, to a chemical agent, modified by some unknown electric circumstance.

Fabroni was the first who attempted to prove, that the phenomena of Galvanism proceeded from a mere chemical operation; this opinion first arose from a variety of observations, which he had made on the mutual action which different metals exert on each other; and on the great tendency which one metal has to oxydate when in contact with another. That the simple contact of two different metals when exposed to a fluid, produces a particu-

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* See Journal de Chimie.

lar tendency in one of them to oxydate, may be clearly proved in the following manner:—Place a plate of zinc, and a plate of silver in a glass, containing a dilute solution of sulphuric acid, no change at first seems to take place in the metals, but bring the two metals into contact, and bubbles of air will be seen to arise rapidly from the zinc, a speedy oxydation commencing by a decomposition of the water, the zinc abstracting its oxygen, with which it enters into combination, while the hydrogen is let free. This certainly may be called a Galvanic operation, and explains a fact which was not before well understood. Ships which were sheathed with copper, and fastened with iron bolts, were found to be injured in the sheathing, by the bolts having become loose when exposed for a short time to the salt water, while other bolts which were not in contact with copper were but in a slight degree injured. The cause of this is now sufficiently obvious, here are two dissimilar metals and one fluid, a rapid oxydation of the iron therefore takes place by its contact with the copper while exposed to the salt water. Fabroni certainly reasons very ingeniously on these facts, and though he does not mean to exclude all electrical influence, it is not surprising that he should refer many of the phenomena to a chemical process taking place in the metals, he considers it to be a slow combustion and oxydation of the metal, accompanied by an attraction of oxygen, and a disengage-

ment of light and caloric ;—to produce this, it is necessary that some fluid, such as the Lymph, Saliva, or any other humidity should be present, and to these changes he thinks the different sensations on the animal fibre should be ascribed.

Crove, observing these chemical changes which take place in every Galvanic operation, and the necessity which there is, that the muscles should be surrounded with humidity in order to produce the shock, is inclined to attribute it to the decomposition of a fluid ; that the shock is accompanied with the decomposition of a fluid is very possible, and so necessary is humidity to produce this shock, that it is known no such sensation can take place even on the tongue by the action of the metals if it has been previously wiped dry ; that in all Galvanic experiments a fluid is decomposed, appears highly probable, but that the decomposition of this fluid explains all the Galvanic phenomena is by no means proved, though many processes in the animal œconomy may be attempted to be explained on the same principle, and seem to have some connection with the Galvanic operation. Respiration for instance may thus be called a Galvanic process, a decomposition of the air always taking place during the operation. This, it appears, is the stimulus which Nature employs to rouse into action animated matter, respiration being at once suspended when the lungs are

are deprived of this fluid. Modern Surgeons are well acquainted with the pain and inconvenience which arise from too long an exposure of a fore to the atmosphere; but they could, till lately, have no idea of accounting for it on such principles as are here attempted; the theory of Creve, will, however, afford an explanation of it, by shewing that, while a decomposition of a fluid is taking place, the oxygen entering into a new combination, appears to be that stimulus which gives pain and irritation.

These attempts to explain Galvanic phenomena, are combated by Volta, who seems disposed to attribute the whole of them to the electric fluid, and if it is true that the Leyden vial can be charged with the Galvanic pile, it must be confessed that it goes nearly to establish the identity of the two fluids; but this has not succeeded with the most experienced philosophers in this country. Volta is of opinion that the Galvanic is nothing more than the common electric fluid, excited by the mutual contact of the metals, and that the humid substances applied to the plates answer no purpose, but establishing a reciprocal action, or communication between them, so as to impel the electric fluid in one particular direction; and the reason why saline substances succeed better than any other, is, he says, only because they act as better conductors than pure water; the chemical phenomena which are observed, he thinks are only

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connected with it, as being secondary effects of the electricity.

Mr. Davy, to whom this science is indebted for much valuable information, has followed up the experiments of Fabroni and others ; and in a very ingenious paper, in the Philosophical Journal, * has gone farther to explain the theory of Galvanism than any other person. He first found that the zinc of the Galvanic pile does not oxydate in pure water : by pure water is meant, water holding in solution no oxygen gas, no nitrous gas, and no acids.

This he proves clearly from a variety of circumstances ; he also proves that the power of the pile is greatly increased by dipping it into nitrous or marine acids, which enables the zinc to oxydate itself more rapidly ; and that when pure water is made use of, in the construction of the pile, it is capable of but little Galvanic effect. From which it appears that Volta's pile only acts when the fluid between the plates is capable of oxydating the zinc ; and that in proportion to the quantity of oxygen which enters into the zinc, so is the power of the pile to give the shock, or to decompose water. He therefore, with great reason, concludes that the chemical changes which take place by the oxydation of the zinc, are, some how or other, the cause of the electrical effect.

* Vol. iv. p. 340.

He also has since added considerably to our store of information on this subject, and has found that single metallic plates, connected together by different fluids, were capable of strong Galvanic effects.

It will, perhaps, be never satisfactorily explained how this Galvanic influence is caused; that chemical changes take place in the metals, there can be no doubt, and that their Galvanic power is much greater while this change is going on, is also ascertained by a variety of experiments: but Mr. Davy has not only taught us that strong Galvanic effects may be produced with one metal, but that the metals are not absolutely necessary; this has been lately confirmed by some extraordinary experiments on the animal fibre.

The circumstances attending this discovery were first related in Nicolson's Journal, and are so extraordinary that we should be inclined to discredit them, were they not verified by the names of men of high literary character. Mr. Aldini, nephew of the celebrated Galvani, has since published his experiments, which prove that the Galvanic matter is generated or collected in the bodies of animals, and has succeeded in exciting muscular contractions in a frog without the aid of a metal. The manner in which, he says, he performed these experiments, were first by laying bare the nerves of a
frog;

frog; he took hold of the muscular part with one hand, while with the other he touched the nerve, and contractions took place as in the former Galvanic experiments.

Secondly, he takes the head of an ox, recently cut off, and touching the spinal marrow with a finger wetted with salt water, he makes the crural nerves of a frog, which he holds in the other hand, touch the tongue of the ox, and whenever this contact takes place, violent contractions are produced in the frog. These experiments, if correct, shew that an animal circle, capable of Galvanic effects, may be formed as well as a metallic one.

These experiments were made in October 1803, by Aldini, who considers himself the first discoverer of what he called Animal Galvanism, but this was long before suspected by Mr. Davy, and in a paper of his, so late as January, 1801, he says, "I have lately made some experiments, which convince me, that there exists in living matter Galvanic action, independent of all influence generated by metallic oxydation. On the whole, no Theory as yet attempted, has explained the different phenomena which are produced by the Galvanic process, and whatever credit we should be inclined to give to the arguments which attribute every thing to the chemical changes which take place in the metals, still we must

must hesitate in assenting to it, after the discoveries which have been made, not only of the same effects being produced in some instances with one metal, but also that to produce some of the most striking Galvanic phenomena, the metals are by no means necessary.

To conclude:—though the complete identity of the Galvanic and electric fluids remains to be proved, yet there are so many circumstances to favour this opinion, that it appears to rest at present on safer principles than any other; it is only by collecting facts, arranging and comparing them that we can expect to establish any rational theory, and it is to be lamented, that neglecting this in Galvanism as in other sciences, some philosophers begin by forming plausible theories, which are neither supported by facts or experience.

Neither the design, nor the limits of these outlines, will permit me to notice the opinions of a great number of philosophers who have wrote on the present subject, such as have appeared either plausible or consistent, I have given you a sketch of; while it still continues to excite both interest and attention, it should be the province of the Physician not to neglect the advantages which may be derived from its application to Medicine; in this way, while his curiosity is excited, and his ardent love of science indulged,

dulged, by converting his knowledge to so useful a purpose, as the cure of diseases, he may entitle himself to the approbation of his own mind, and to the esteem and gratitude of his fellow-creatures.

ON THE
APPLICATION OF GALVANISM,

TO

M E D I C I N E.

HAVING traced the connection between electricity and Galvanism, and examined with precision their respective powers on the animal fibre, I should indeed have thought my time very much misapplied, if I had not bestowed considerable attention on its effects in the cure of a variety of diseases; curious as are many of its most important phenomena, yet the subject would perhaps appear less interesting, if it were not found capable of being applied to some useful purpose. As soon, therefore, as the powers of the pile of Volta became known, it was natural to expect that Physicians should attempt to make use of its influence as a medical agent, and few I believe who have paid any attention to the subject, will deny, that it promises to exceed any other stimulant in Nature. Having so many properties different from electricity, it was natural to expect, that its effect on the nervous system would be also different, it has accordingly been much used of late in Medicine, and some late experiments

periments of Aldini, shew that its effects are not confined to the living animal, but that it is also capable of exciting the vital powers a considerable time after death, producing the most horrible contortions and grimaces of the muscles of the head and face in animals, some hours deprived of life. When we consider, therefore, the influence which even a small quantity of this fluid exerts on the muscles of an animal, even after death, is it not reasonable to conclude, that the Galvanic current passed through a diseased part, may in many instances be attended with the best effects? It admits of an easy application to any part of the body, and may be applied for any length of time, with little labour on the part of the operator, and less inconvenience to the patient, its action may be easily increased or diminished according to the indications of cure, and it must be also observed, that there is this difference between Galvanism and electricity, that the Leyden vial, when once discharged, exhibits no more effects, without renewing the charge, whereas, Volta's pile continues undiminished in strength, and constantly charges itself.

Before we take a view of the different diseases to which Galvanism is applicable, we should first consider what are its uniform and constant effects on the animal frame, and let it be first recollected, that the sensation produced by it is peculiar, and cannot be imitated

imitated by electricity; on the intellectual organs in particular its powers differ materially, and when judiciously managed, the sensation is described as by no means disagreeable.

It is also a curious circumstance that when the powers of the mind are cut off, the effect of Galvanism on the animal body is more powerful: Thus, a paralytic limb will be thrown into spasmodic action by a charge, which in a healthy person will produce no such effect. That the will is the cause of this may be explained by another fact. If a very small Galvanic shock is passed through the limb of a person asleep, violent spasmodic contractions will take place in the muscles, but the same charge being applied to a person whose mind is engaged, scarcely produces any sensible effect. There seems therefore, to be a principle existing in the living animal which enables it to resist powerful external stimuli, and thus it is explained how an inanimate body is more violently affected than an animated one.

Having ascertained that the immediate effect of Galvanism on the system, is that of a very powerful and peculiar stimulus,—it requires only the discernment of a judicious Physician, to determine what are the diseases where it may be applied with safety or success. It will be obvious that it can be only employed with propriety in diseases arising
either

either from a defective energy of the brain, or a debility in any of the members or functions of the body, arising from a general or partial cessation of nervous power, or loss of tone in any particular part. This, therefore, being laid down as a principle, it will naturally occur that in no disease can Galvanism promise more benefit than in paralysis. It has indeed been proposed as a remedy in apoplexy, but this is a disorder that requires much caution, in the application of so powerful a stimulus, in certain cases of it unattended with an accumulation of blood in the vessels of the brain, or a decided determination to the head, perhaps it may be attempted with safety; however, in paralysis, the frequent termination of apoplexy, no such danger is to be apprehended, and where there is total loss of motion, and but little sensibility in the limb, the greatest advantage may be expected, by a proper application of this stimulus, which may be increased on some occasions to any proportion.

Should Galvanism, applied in the common way to the limb, appear to have but little effect, a much greater state of irritation, or stimulus may be produced, by first applying small blisters to each extremity, and while the cuticle is bare passing the Galvanic current through the limb, by touching the conductor to those parts where the blisters had been applied.

When

When the tongue is also affected with palsy, and the powers of articulation either impeded or destroyed, nothing as yet attempted has succeeded so frequently as Galvanism; by passing repeated shocks between the nape of the neck, and the tongue, I have succeeded in restoring the organs of speech in a few moments to a person who could not express a word so distinct as to be understood. In this case the tongue was the only part affected in a man apparently otherwise healthy, and it was described to have occurred after an apöplectic attack with which he was seized at night, but soon recovered from. I must however, confess, that the effect of Galvanism was little more than temporary, he could immediately after it speak perfectly distinct, but in the course of the day relapsed again; on the whole, he was greatly relieved, but did not persevere long enough to give the remedy a fair trial.

In illustration of the power of Galvanism in paralysis, I shall mention the following case which occurred to me.

I was lately requested by a very scientific medical friend, to try the effect of Galvanism on a patient of his, a lady about fifty years of age, who had been for some time in ill-health, the consequence of Menorrhagia, and was attacked about a year before with apoplexy, from which she recovered at the time, leaving her left side in a complete state of paralysis,

ralysis, her tongue also affected, and the powers of articulation greatly impaired. She was treated for these symptoms in the usual manner, and had been electrified for a considerable time with little benefit, her general health became more impaired, she had one or two attacks of apoplexy, and became œdematous with other symptoms of dropy: this complaint, however, was nearly removed by the use of Digitalis, and, except a considerable œdema in the palsied leg and arm, no other symptoms of dropy appeared; on the whole, I did not consider it a very favourable case to attempt the trial of Galvanism: however a battery of fifty plates were prepared, and the first application was made to the hand and arm of the palsied side. The effect was here very surprising, even on the first day, the limb which was pale and enormously swelled, began to resume its natural heat and colour, and its powers on the absorbent system, were so remarkable, that the swelling of the arm totally disappeared in two days; the limb which before was nearly useless, gradually began to recover its power of motion, and the fingers which were fast clinched and contracted, gave way on every Galvanic shock; small shocks were then passed through the tongue, which produced considerable irritation, and a copious flow of saliva from the salivary glands; her speech after each attempt became evidently improved, blisters were then applied to the hip and foot of the affected side,

side, and the Galvanic current passed through the limb, the œdema here also disappeared and the motion of the leg was so far improved, as to enable her, to walk, she continued rapidly recovering; the use of the hand and arm being nearly restored, when on the ninth day she was seized with another apoplectic fit, which carried her off in a few hours: but what became singularly curious in this case, was that the side originally affected with paralysis, did not suffer, but during the short time she lived continued well, while the other side became paralytic, this is, I apprehend, a very unusual instance, and though Galvanism could not be said to be completely successful, yet its powers on the system seem by it perfectly ascertained, and make it probable that the effect was such as nearly to establish a healthy state in the side affected, and render it less liable to be influenced by the original organic affection of the brain; which neither in this, nor indeed in any case can it be expected to remove. It was also the first instance where I had an opportunity of observing its powers in stimulating the absorbents to act; this, as far as I am acquainted with, has not been before noticed, and so extraordinary was its effect in rapidly causing the œdema to subside, that I am persuaded no application whatever, in such cases, will be attended with the same advantage; here it appears to act as a safe and local stimulant, restoring the natural heat and colour of the limb, and by increasing

the languid circulation of the part enables the different vessels to perform their proper functions and recover their lost tone.

If such are its powers, it will naturally induce us to try its effects in some diseases of the Lymphatic system, which at present, are but imperfectly understood; Mr. White has described a complaint, to which women in the puerperal state are chiefly liable:—This consists in a swelling of the lower extremities, unattended with external inflammation, the skin being smooth, shining, and pale; much difference of opinion exists, both as to the cause and mode of treatment of this disease: it is allowed on all hands, to be an affection of the Lymphatic system, either occasioned by increased exhalation, or diminished absorption. Doctor Ferriar attributes the disease to an inflammation of the Lymphatics, while Mr. White asserts, that if this ever takes place, it is the effect, not the cause of the disease. Perhaps in this, as in many other instances, the difference between active and passive inflammation is not well defined; as, if any active inflammation takes place, blisters and other external stimulants would never succeed, and those are the remedies allowed even by Doctor Ferriar to be attended with the most advantage. It is evident, from the appearance of the limb, that the absorption is not equal to the effusion, and from what I have observed I know of no remedy so capable of rousing

rousing the vessels into action, and promoting absorption as Galvanism, while at the same time, its influence is so completely under our command, that no danger can be apprehended from its judicious application.

In the case which I have just detailed, the effect of Galvanism was also remarkable, for the influence which it had in producing an immediate relaxation of the contracted fingers, and in every such instance where I have applied it, I have uniformly found the same result. In rigidity therefore of the joints, whether the consequence of the gout, or rheumatism, it promises much advantage, and the same circumstances that favor its application in those diseases, will also encourage us to hope that it may be of equal efficacy in tetanus or locked jaw, a disease both frequent and fatal in warm climates; none but those who have seen the effect of Galvanism in producing a relaxation in any muscle when in a state of contraction or involuntary action, can have an idea of its power on the nervous system; locked jaw is one of those complaints, in which the patient is frequently lost from the inability to take either food or medicine; if, therefore, Galvanism answers no other purpose than the temporary relief of relaxing the spasm and opening the jaw, which I am persuaded it will generally do, it is so far of use as counteracting the most distressing symptom, and enabling the

patient to take the necessary nourishment as well as medicine.

There are a number of diseases so particularly adapted from their nature and situation to the influence of Galvanism, that the experienced Physician will be at no loss to decide when it may with propriety be employed. In amaurosis, or loss of sight, supposed most frequently to arise from a paralysis of the optic nerve, what remedy seems more suitable, or can be applied with more convenience? In cataract, which is occasioned by an opacity of the crystalline humour, it can promise but little success; the complaint arising from a local cause, and seldom removed except by an operation; however, it does not appear improbable but Galvanism may afford the Surgeon some criterion for judging whether the optic nerve is also diseased, or whether impressions of light can be received on the retina; if this should appear to be the case, the removal of the lens will restore the sight of the eye. This in general may be determined by the patient perceiving the flash of light from a proper application of the Galvanic stimulus, which I have never seen fail in a perfect healthy state of the eye, or when impressions of light are felt on the retina.

Galvanism has been tried with great success in deafness, but in no disease is it more difficult to distinguish

tinguish the cause than in this, and on this circumstance alone arise the frequent contradictory reports which we have of it; it is the promiscuous use of this, or any other remedy without a knowledge of the cause of diseases, which has brought many of our most valuable remedies into disrepute, and which marks the distinction between the Physician and the Empiric. The application of a very valuable remedy at an improper time, or in a disease to which it is not suited, may leave unfavourable impressions to which in itself, it is by no means entitled;—thus, the application of Galvanism in apoplexy, arising from too great an excitement, whether general or local, will aggravate the morbid symptoms, and increase the disease. This cannot be too strongly inculcated, as well as another obvious circumstance, which is, where the disease arises from mechanical injury, no advantage can be expected till that is first removed; thus, for example:—I was lately requested to Galvanise a very fine boy who had lost the use of the arm and hand, it was much emaciated, had lost all power of motion, and the circulation even in the limb could scarcely be perceived; on making proper enquiry into the cause of these symptoms, I found that they all arose from a dislocation of the arm some years before, which was never reduced, the consequence was, a compression on the nerves and arteries leading to the

the limb; here then was a case, where no remedy without the reduction of the limb could be of any service, and where Galvanism would be tried in vain, by a careless observer. Let it therefore be recollected, that before Galvanism is attempted in cases of deafness, that one great object is to ascertain from what cause it arises; should it be occasioned by any organic injury of the membrana tympani, which is frequently produced by abscesses in the ear, or should it arise from mal-conformation in any of the femicircular canals which may induce a mechanical obstruction, then no advantage can be expected from this remedy;—but if it is ascertained to arise from a defective energy of the auditory nerves, or a relaxation or paralysis of the membrana tympani, then have we every reason to expect success: in some cases, even when there is a want of secretion of wax, hearing is impeded, and the stimulus of Galvanism may tend to restore this secretion so necessary to a healthy state of the ear.

There are few diseases more obstinate in their nature, or more painful to the patient, than rheumatism; however, after what has already been observed, it will occur, that it is only in the chronic species that any advantage can be expected from Galvanism, and without entering into the different theories of Galvani and others, ascribing this disease to extravasated humours stagnant round the surface of the nerves,

which

which theories are neither supported by facts, or experience, I can have no hesitation in recommending the stimulus of Galvanism in obstinate cases of chronic rheumatism, unattended with symptoms of general or topical inflammation. It is particularly important, however, to attend to this, I have in one case seen it aggravate considerably the painful symptoms, which I look on as a certain proof that the disorder then partook in some degree of the acute species, though the pulse, and other circumstances gave no reason to suspect it; indeed it is frequently difficult to distinguish between these two states of rheumatism; Galvanism, however, seems capable of affording a diagnostic, and I should be inclined to attribute the disease to the acute species, when the application of Galvanism so far from giving relief, increases the painful and other distressing symptoms of the complaint.

The same circumstances that would lead us to employ it in this case would also recommend it as a most useful remedy in indolent tumours or scrophulous swellings, which have long remained stationary unattended with pain or inflammation; here such a stimulus is peculiarly wanting, and if it does not cause the resolution of the tumour it will tend to bring on a suppuration, which in such cases is frequently an object to be wished. In scrophulous habits, buboes arising from a venereal cause will put
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on such an indolent appearance, as that neither can they be dispersed by suppuration, or resolution; here Galvanism is particularly safe and applicable, and Mr. Wilkinson and others, state, that in such cases they have employed it with great advantage.

When electricity was first employed in the cure of diseases, it did not escape the observation of Physicians; that it may be applied with success in obstinate cases of Amenorrhœa, it has accordingly been used with evident advantage in a variety of instances, but with the knowledge which we at present possess of the powers of Galvanism, there appears no disease where it should have a more decided preference over electricity than in this; from the delicacy and timidity of the sex who are the subjects of this disorder, electricity has never had a fair trial; nor does the electric shock seem calculated to remove such a complaint, while it becomes an object of fear and alarm, passions more calculated to impede than to increase the flow of the menses; if, however, the powers of Galvanism are applied with judgment and discretion, and with due regard to the feelings of the patient, its peculiar stimulus may excite such an action in the vessels as may restore the determination to the uterine system.

From the powerful action of Galvanism on the system, even after life appears extinguished, it has
been

been suggested by Creve that it may be the means of distinguishing real from apparent death. This is controverted by Humbolt and others, yet it will appear evident, that in some cases considerable advantage may be derived from it, though no decided reliance should be placed in it alone; when we are not certain of the length of time that the principle of life has appeared extinguished, and when waiting for the putrefactive process, is attended with inconvenience, the simple application of this stimulus to the body will determine, whether all irritability in the muscles is destroyed, and of course, whether persevering in any remedy for the restoration of the vital principle will hold out any prospect of success. In cases of suspended animation, whether from drowning or other causes, no doubt can be entertained that it may be at least a useful assistant; we have instances where life has appeared to return, but still the patient has been lost for want of such a general stimulus as this, capable of rousing the dormant spark of life, and stimulating the heart and arteries to action.

I would not have it understood that this alone will be sufficient; on the contrary, the usual judicious remedies should be tried, but in addition to those on all occasions, I would recommend the powerful stimulus of Galvanism, and it only appears surprising, that so little notice has been as yet taken

of it in the instructions delivered by the different Humane Societies, or that we should have so few well authenticated instances of the effects of it in suspended animation.

While we are engaged in attempting the removal of some of the most dangerous bodily diseases by Galvanism, perhaps it may not be altogether superfluous to attend to its action in diseases of the mind; Aldini I believe first attempted in such cases the use of it, and says, that he has completely succeeded in two cases of mania, attended with melancholia; if it should be found equally useful in the hands of others, how valuable a remedy have we for a disease hitherto so little understood, for much as we are in the dark with regard to other diseases, there are none with which we are more profoundly so than insanity. It unfortunately happens that Physicians engaged in extensive practice, neglect the study of mental diseases, forgetting the connection between diseases of the mind and of the body, they leave this part of the profession to men little calculated for it by education, and less perhaps from their ignorance of Medicine; while this is the case, and such patients are left to the mercy and discretion of keepers, diseases of the intellectual organs will continue to be treated with Empiricism; remedies by no means adapted will be tried, Stimulants will be used where already there is too great an excitement, and

and evacnants persevered in where moderate stimulants may succeed; this only can account for the few who return from insane asylums, free from one of the most distressing maladies which falls to the lot of human nature;—to treat this subject as it deserves, I feel myself but little qualified; but it must be allowed, that the Physician who does not in all cases attend to the influence of the mind on diseases, as well as of diseases on the mind, deserves but little the confidence of his patient.

To lay down rules for the application of Galvanism to the intellectual organs, in every instance, would exceed the limits of this essay; the same cautions before delivered against the use of stimulants, in cases of great excitement, are here more particularly necessary:—therefore, in a high degree of mania, or delirium, I should not consider Galvanism a safe remedy, but where there is an evident diminution of the energies of the mind, the propriety of it cannot be doubted; this is a very frequent cause of mental derangement, occasioned by impressions made on the sensorium by the depressing passions, producing, in some cases, melancholia, in others, hypochondriasis; each of these states of derangement are accompanied with such a torpor in the Vascular system, a deficiency of muscular energy, and a languor of the whole frame, as to promise considerable success from the powerful and peculiar stimulus of Galvanism.

nism; it should not here be omitted, that in case of Hydrophobia, Galvanism has been said to have succeeded. This is an instance of mental derangement arising from the absorption of a peculiar poison, attended with symptoms so fatal and distressing, that were the powers of this remedy well ascertained, few improvements, in modern times, would rival the advantages which the world may expect from the discoveries of Galvani.

Having taken a short view of the diseases where Galvanism may be applied with advantage, it may not, perhaps, appear here unnecessary, to take some notice of Perkin's metallic tractors.

It is probable that when the proprietor first thought of applying these instruments to the cure of diseases, he had some idea of the discoveries of Galvani, which were made at that period; under impressions arising from this discovery, and ignorant as he must have then been of the science of Galvanism, it is not surprising that he should have had erroneous opinions on the subject, while at the same time the imaginations of the weak and the ignorant were so easily operated on. Many Persons of enlightened understandings were for a considerable time dupes to the fashionable remedy, called Animal Magnetism, now acknowledged to be a deception. But when we read in Perkin's advertisement,

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a list of the numerous and contradictory diseases for which his Tractors are recommended, and also that they are "equally applicable to all analogous diseases of horses;" should we not hesitate before we assent to such a combination of absurdity?

Sufficient is now known of the mode of exciting the nervous or muscular energy, by the Galvanic or animal circle, to induce the enlightened and judicious Physician to discard those trifling toys, the offspring of ignorance and Empiricism.

It is scarcely necessary to add, that the metals selected by the proprietor of these instruments are not those best calculated to produce Galvanic effects; and that the mode recommended for their use, is inapplicable to any useful purpose, and totally inconsistent with the knowledge which we at present possess of the science of Galvanism.

As it also is evident, from the late experiments of Doctor Hagarth: that they possess no specific power derived from the metals, they should be considered as a popular delusion, and their effects ascribed to impressions of the imagination, which it is well known, have not only particular influence in the removal, but in the formation of diseases.

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I should not have thought it necessary to say thus much, but that I have heard it gravely asserted by persons both of talents and education, that they can now easily explain the operation of the metallic Tractors.

Nearly on the same principle, another remedy, called the Galvanic belt, has been recommended, and for which no doubt the proprietor will obtain a patent. Of this, however, I will not speak so harshly, but certainly, neither its construction or mode of application is in any degree reconcileable to the known laws of Galvanism. Let us, therefore, at present, be satisfied with its medical effects, as connected with the pile of Volta. It may not, nor can any remedy always succeed; but thus much we know, that its principles are unerring, and that its effects are always obvious, such as a constant and powerful excitement of the nervous influence, and a local or general stimulus to the system.

I have thus, my dear Sir, endeavoured to give you a few of the outlines of the science of Galvanism, and its application to the cure of diseases;—many of these facts which I have described must have been long since familiar to *you*; but few others, however, have either the taste, or the inclination, to investigate subjects so unconnected, in appearance, with

with their ordinary pursuits. To such men I cannot address myself more forcibly, than in the language of my friend, Mr. Davy, in his Preliminary Lecture on the Study of Chemistry.

He calls their attention to this science, by observing, that—"To men collected in great cities, who are wearied by the constant recurrence of similar artificial pursuits and objects, and who are in need of sources of permanent attachment, the cultivation of Chemistry and the physical sciences may be eminently beneficial; for in all their applications they exhibit almost an infinite variety of effects connected with a simplicity of design. They demonstrate, that every Being is intended for some definite end or purpose; they attach feelings of importance even to inanimate objects, and they furnish to the mind means of obtaining enjoyment unconnected either with the labour or misery of others."

"To the man of business, or mechanical employment, the pursuit of experimental research may afford a simple pleasure, unconnected with the gratification of unnecessary wants, and leading to such an expansion of the faculties of the mind as must give it dignity and power.

"To the refined and fashionable classes of society it may become a source of consolation and
happiness

happinefs in thofe moments of folitude, when the habits of the world are confidered with indifference. It may deftroy difeafes of the imagination, owing to too deep a fenfibility, and it may attach the affections to objects ufeul and permanent.”

To thefe inducements I may add, that if in the purfuit of fo interefting a fludy, the philofopher fhould fucceed in the difcovery of fome new remedy for the cure of difeafes, or in the application of the fcience to any of the ufeul arts, he muft feel a gratification arifing in his own breaft, which thofe only are acquainted with, who devote their leifure hours to the attainment of ufeul knowledge, and who apply this knowledge to the improvement of the arts, and to the benefit of fociety.

DIRECTIONS

FOR THE CONSTRUCTION OF THE

GALVANIC APPARATUS,

AND APPLYING IT TO USE.

IN order perfectly to understand the theory and practice of Galvanism as far as we are at present acquainted with it: I shall first repeat, that all Galvanic combinations are either made with two dissimilar metals, and one fluid, or with two dissimilar fluids, and one metal, and that in the former case the greatest effect is produced, when one of the metals is easily oxydated and the other not acted on.—When only one metal is used something similar occurs, one side of the plate should be exposed to a fluid capable of acting on it, while the other side is connected with a fluid of a different nature.

To explain those simple Galvanic combinations which have led to so many important discoveries, and gave rise to the pile of Volta, I have annexed the following figures—

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Galva-

Galvani's first discovery will be easily understood by a reference to Plate I. Fig. I. A represents a prepared frog, that is a frog skinned, with part of the vertebre and the sciatic nerve laid bare, suspended on a rod of zinc, B. In order to produce violent spasmodic action in this frog, nothing more is necessary than to touch the zinc rod with a silver probe, and then complete the circle by touching the feet of the animal, the whole limb will then be thrown into violent commotions, which will be renewed as often as the contact is made. However, in order to shew the same experiment in a different way, Fig. II. represents a prepared frog, with that part of the spine to which the sciatic nerve is attached, placed on a plate of zinc, Z. while its feet are placed on a plate of silver, S. The communication being made by the conductor R. the frog is thrown into violent convulsions, as often as the circle is formed.

These shew the influence of two metals in producing Galvanic effects, and frogs are selected for this purpose, as their muscular fibres are so extremely sensible to the electric, or Galvanic influence, that they become the most delicate electroscopes hitherto known. However, in performing these experiments, the necessity of humidity must not be forgot; if the muscles of the frog should become dry by the animal having been too long killed, no effect is produced, and during each experiment the

the process of oxydation appears on the surface of the zinc where it is exposed to the moisture of the frog, which farther shews that in all Galvanic experiments a decomposition of a fluid takes place.

In order to shew that a Galvanic combination may be formed with two dissimilar fluids, and one metal, take a glass vessel B. Fig. III. fill this vessel with water, and place in it a small silver cup S. which should be nearly filled with dilute nitrous acid. Thus the two fluids are not in contact, and one side of the metal is exposed to a fluid which is capable of acting on it, while its external surface is in contact with another fluid with which it has no affinity;—when, therefore, a frog is made to form the communication as at C. the same convulsive motions will take place in the muscles as in the former experiments.

Having seen the effect produced by simple Galvanic combinations on the nerves of an animal, as first discovered by Galvani, it next becomes necessary to describe the construction of the pile of Volta, an instrument simple in itself, but capable of producing very powerful effects.

In the former pages detailing the origin of Galvanism, I have mentioned that the metals best calculated to produce Galvanic phenomena are gold,

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silver,

silver, and copper, when used in conjunction with zinc, tin, or lead, and it is also observed, that the most perfect Galvanic combination is formed when one of the metals undergoes the greatest change, and the other the least.

In the experiments which I have detailed, it is taken for granted that the pile is made of plates of silver and zinc, these being the metals which experience has taught us produce the most powerful effects; silver is however too valuable and scarce an article to become very generally used, and from my own experience, I perceive so little difference between this metal and copper when used in conjunction with zinc, that I see no objection to the general use of the latter, the difference being only about eighty-five to one hundred. When the pile as constructed by Volta, and shewn in Fig. IV is used, about twenty pieces of each metal will be sufficient for performing many interesting experiments, beginning first with a plate of copper, and terminating it with zinc, it may be supported in a frame such as is used for the common hour-glasses, but the uprights which touch the metals should be of glass, or a non-conductor, pieces of woollen cloth are much better than card or leather to interpose between the plates, they should not be quite so large as the plates, and they should be well soaked for some time in the fluid, and then pressed, lest the liquor should run off
and

and wet the edges, which would materially injure the operation of the pile. The fluids which are most convenient and powerful, are dilute solutions of nitrous, or marine acids, about thirty parts of water to one of the acid, solutions of common salt, or muriate of Ammonia may be also used for this purpose, but they are by no means so powerful, and are attended with inconvenience, an efflorescence forming on the plates, in consequence of the decomposition of both salts allowing the Alkali, particularly the Ammonia to attack the copper. When it is intended to take the shocks with this instrument, a flat piece of copper should be placed under the lower plate, one end of which may be bent and turned down into a cup of water, thus, by dipping one hand into the water, and touching the upper plate with the other hand wet, shocks of any intensity may be received in proportion to the number of plates engaged in the circle.

The pile constructed in this manner, and consisting of a series of simple Galvanic combinations may be called a battery, it will not continue capable of action for many hours, as soon as the cloths begin to dry, or the plates to oxydate, it loses its power, and this is accelerated by the unavoidable and unequal pressure of the plates on the wet cloth, which soon forces the liquor out, and by its running down the sides, and forming a communication between one
plate

plate and another, it not only injures the strength of the pile but is attended with many inconveniences. To remedy this, it is soon necessary to take down the pile to wet the cloth and clean the plates. Volta himself saw the inconvenience of this, and endeavoured to counteract it by applying cement to each plate, and filling these cells thus formed with a fluid; however, this was a very ineffectual attempt, which, as far as I have learned, has never been improved on. It required considerable ingenuity to prepare a battery which would not be liable to the same objections; however, on explaining the advantages attending such an apparatus, formed without the inconvenience attending the pile of Volta.—Mr. Michael Fitzgerald, of this town, undertook to construct one, which would remove the necessity of using wet cloth in the formation of the pile; and I should do him injustice did I not acknowledge, that the instrument which he has invented, as described in Plate I. Fig. V. & VI. is finished with that precision and skill, which could only be performed by an Artist who had talents to conceive, and abilities to execute the most difficult pieces of mechanism.—Modest and unassuming merit, the too frequent attendant on real genius, has only kept this self-taught Artist in a situation where his talents have but few opportunities of being either sufficiently known, or rewarded.

The apparatus which I allude to, must be acknowledged as the first great improvement on the pile of Volta, without altogether deviating from its original construction. For medical purposes I have found it a very convenient instrument, and have shewn it to many gentlemen of science, who highly approve of it;—convenient as it is on a small scale for such a purpose, it still may be rendered more so, when plates of large dimensions are used,; as they may be constructed in the same manner, of any size, and as they can be easily taken asunder and separated, they are not attended with the inconvenience arising from large troughs as used at present. It may, perhaps, be also observed, that the pile formed in this manner, bears a closer analogy to the electric organs of the Torpedo than any other, and very beautifully illustrates the construction of the cells in this animal, which appear to be so intimately connected with its electrical power. At the same time, I am free to confess, that even this instrument, in some respects, is not perfect; and that it takes more time and trouble in preparing it than the trough as contrived by the ingenious Mr. Cruickshank, which has become of general use, and which I shall now describe—

It had been tried without success, to excite a permanent electric current without friction, or any active agent. The pile of Volta, it is true, had this effect,

effect, but it became necessary to construct a machine which would answer the same purpose, and could be applied to many of the experiments in Galvanism with more promptness and success.— This has, in my opinion, been completely done, by the invention of the trough such as I have given in Plate II. Fig. IV. To construct this, it is only necessary to get a piece of hard and well seasoned timber, such as oak, or mahogany, and to have it scooped in the shape of a trough, according to the number and size of your plates, which it must exactly fit; but grooves in the timber, as directed by Mr. Cruickshank, are not necessary. The inside of the trough should be coated with a layer of cement about the sixth of an inch thick, and perfectly uniform and smooth. The best cement which I have found for this purpose is bees-wax and rosin, in the proportion of about four parts of the latter to one of the former; when this is well melted, a small quantity of red lead, or a little fine brick dust may be added, it is then fit to apply, and should be laid on warm. The plates which were at first used were semicircular, but these have no particular advantage, and square ones are now substituted, as so much more surface is exposed to action;—it is not necessary that the zinc plate should be thicker than a crown piece, and the copper may be much thinner, they should be made as smooth as possible, and soldered in the common way together, nor is it absolutely

lately necessary that they should touch at all points, but they should be particularly well done at the edges to prevent the fluid from getting access; having heated these plates sufficiently to melt the cement in passing, stick them in the trough about a fourth of an inch asunder, being particularly careful that each plate follows in succession;—copper, zinc, and then copper, and also that they are so accurately fixed that no fluid can pass from one cell to the other. It is found that metals slightly allayed will answer perfectly well. The greatest difficulty which occurs, is forming the plates of zinc, they will not bear the hammer or the roller to shape them, and as this metal is so volatile that it sublimes in the open air, it is necessary that it should be fused in close vessels, and shaped in molds of sand, or what is much better, in brass molds, as by this means its surface comes out perfectly smooth and polished. The braziers understand this sufficiently well, but it is necessary to observe that few of them know zinc by any other name than spelter. Ignorance of this circumstance put me to much inconvenience in my first enquiries. Having constructed a trough in this manner, nothing more is necessary but to adapt it to use: for this purpose, the cells should be filled with a fluid capable of exciting it; weak solutions of muriate of Soda, or muriate of Ammonia answer this purpose in some degree, but for the reasons before stated, dilute nitrous, or marine acids are much to

be preferred, as the more active the fluid, the more powerful will be the effect; but even this has its limits, as should concentrated acids be used, they not only act on the zinc, but also at the same time on the copper, thereby lessening the power of the battery;—by the rapidity of its action also on the zinc, its surface becomes oxydated, and 'till this is removed the Galvanic operation ceases. In filling the trough, care should be taken that the cells do not overflow, as it would materially injure its action, if the surface of the plates were wet so as to make a communication between one cell and the other; as these neutral salts, or dilute acids are sufficiently powerful, it may not be unnecessary to state here, that the use of pure alkalies in trying experiments with the trough is liable to great inconvenience; they act powerfully on the cement, and in a short time totally destroy the action of the machine. The principal disadvantage attending the construction of the trough is, that it is not easy to come at the plates to clean them, it however so happens, that each successive operation contributes to do so; the first effect of the acid, particularly the marine, is to act on the oxyd on the surface of the zinc plates, then on the metal itself, by which means the action of the battery continues so long as the acid remains unsaturated, or 'till a fresh accumulation of oxyd attaches itself to the surface. The trough must be then emptied,
and

and washed, which is all that is absolutely necessary till it is again charged for use.

The first experiment which is generally tried on this machine, is its powers to give the shock: to perform this, nothing is necessary but to wet the hands with water, and to embrace in each hand such a discharging rod as is given in Plate-2^d. Fig. V. By touching the first cell of the trough with the point of one rod, and any other cell with another, a shock may be received through the arms, the strength of which is in proportion to the number of cells engaged in the circle, and also in some degree to the extent of surface of the body which is wet and exposed to the conductor:—thus touching each end of the trough with the points of the fingers moistened, will by no means produce such a shock as when a large extent of the surface of the skin is exposed to a conducting substance.

Experiment 2nd. To give a shock confined to any circumscribed part of the body, get two pieces of cloth, about the size of a shilling, well soaked in muriate of Ammonia, and place these on each point of the limb, or muscle through which it is intended that the Galvanic influence should pass, let each cloth be then touched with rods communicating with each end of the trough, so as to complete the circle. But it is as necessary here, as in electrical

experiments, that these rods should have all communication cut off with the operator's person by means of non-conductors; they may, therefore, either pass through glass, or part of them may be covered with cement, as in Plate 2^d Fig. VIII. and in order to apply them with more convenience, they are attached to the trough either by brass chains or spiral wires.

This is the way in which Galvanism is applied for medical purposes, and it may be given to any strength, according to the part of the trough to which the wires are connected, and renewed as often as is wished, by mere contact, without any inconvenience, and continues of the same strength as long as the pile continues in action. I have frequently used it myself and applied it in this way to others, and nothing can be more striking than the difference between it and electricity.

If it passes through any part of the cuticle which is wounded, the operation is intolerably painful, and at all times the effect on the muscle through which it passes is highly powerful, producing a visible spasm or contraction, and a sensation resembling the puncture of a number of needles. If the shocks are of any considerable strength, those parts of the limb to which the conductors are applied appear red, and shew some signs of inflammation, which suggests the necessity of some caution in the application of Galvanism

vanism to the more delicate and susceptible organs, to guard against the inconvenience which may arise from too great an excitement.

Thus in the application of Galvanism for the cure of amaurosis, particular care should be taken that the cornea of the eye is guarded from the instrument, otherwise a dangerous inflammation may be induced. In passing the Galvanic shock through the ears, care should be taken to commence with a small charge, and also that the conductor is properly applied, in such cases I have armed the conductor with an ivory ball, which only admits a sufficient part of it to enter the meatus auditorius and prevents the possibility of its injuring the tympanum. When only one ear is affected such a conductor may be introduced and fastened to the head, while shocks are taken with the instrument, represented in Plate 2^d. Fig. V. embraced in the hand of the person affected, and of such strength as may be found safe or proper:—In this way I am engaged at present in applying it in a case of deafness, which if the patient has proper perseverance promises already the most complete success.

Experiment 3rd. To see the flash in a very conspicuous manner, put one of the wires, connected with the copper side of the trough into your mouth, or touch it to your forehead, while with a wet hand
you

you touch the other wire connected with the zinc side;—as often as this contact is made the flash is renewed, accompanied with a very peculiar pungent taste in the mouth.

Experiment 4th. To procure sparks and ignite charcoal, fix small pieces of dry and well burnt charcoal to the points of each conductor, bring these into contact, by this means bright vivid sparks will be obtained, and if the machine is sufficiently strong, the charcoal will not only be ignited, but a continued and brilliant light may be kept up for a considerable time.

Metallic wires may be completely fused in the same manner by connecting them to the conductors, and such an intensity of heat may be produced, if those experiments are performed in oxygen gas, as cannot be imitated by any other process; however, the common pile will not be sufficient for this purpose, the shock, as before observed, is in proportion to the number of plates, at least to a certain extent, while to produce the requisite heat for the fusion or deflagration of metals requires plates of at least eight inches in diameter, fifty of these are sufficient for this purpose, when at the same time they possess no greater degree of power on the animal fibre than the same number only three inches in diameter.

No experiments in Galvanism are more curious than the effects of it in the decomposition of water, or the oxydation and revival of metals. Plate 2^d. Fig. III. represents the apparatus which I have found to answer best for this purpose. The tubes recommended by Messrs. Nicholson and Cruickshank are attended with many inconveniencies, particularly that for receiving the gases separately, as it is a difficult matter to collect them afterwards and submit them to the different tests requisite to ascertain their qualities;—that which I have given Plate 2^d. Fig. II. appears to me free from those objections, the gases are received with great convenience in separate glasses, and may be examined with great accuracy, by which it will appear, that the gas arising from the zinc side is pure oxygen, and that from the copper side of the trough pure hydrogen, in the proportions necessary to form water.

In order to confirm this, let the experiment be tried with such a tube as is given in Plate 2^d. Fig. I. and when the water in this tube has fallen to the point of the upper wire, let an electric spark be passed between the two wires A & B. which will set fire to these two airs, and the water will rise again in the tube;—now as we know by the former experiments, that the tube contained no airs but hydrogen and oxygen, and as there was nothing to
afford

afford these airs but water, we may safely infer that the water was decomposed.

I find this tube more convenient for this experiment than any other; the wire B not being within the Galvanic circle is in no degree connected with the decomposition of the water;—but when this is finished it answers to explode the gases by the electric spark, without taking the tube from the trough, or running any risque of the gas either escaping or being adulterated by the admixture of common air.

It is now known that the gases may be exploded with equal facility by the Galvanic spark, and Mr. Davy has described an apparatus for this purpose, in the Journals of the Royal Institution;—but such a one is by no means necessary. The tube represented Plate 2^d. Fig. III. will answer perfectly well, but it is necessary that the wire C. should be somewhat longer than it is represented, so as to reach about the tenth of an inch above the point of the wire B. as soon as the production of gas ceases, which it will do when the water falls below this wire, nothing more is necessary than to make these two wires touch each other when the communication is made with a large battery: as it will be recollected, that Galvanism differs from electricity perhaps in nothing more than in this circumstance,

circumstance which is the necessity of actual contact between the conductors before any sparks can be drawn.

In order to make experiments on the oxydation of metals, the tube, Fig. III. is used; the wire, which should be of gold, is hermetically sealed to the glass, and the lower wire can be changed at pleasure, by taking off the ring which fastens it to the wire D. which is much thicker, and has a groove to admit it. Thus experiments may be made on silver, copper, or iron wires, all of which are oxydated with different appearances, by connecting them with the zinc side of the trough.

When experiments are made on the revival of metals held in solution by different acids, the same tube will answer, but it is better that both wires should be of gold, particularly in that beautiful experiment of forming the *Arbor Dianæ*; as, if copper wires are used, the silver is precipitated in a metallic state by the union of the copper with the nitrous acid, to which it has a greater affinity. Thus the formation of the metallic needles by the hydrogen would be frustrated, the silver being precipitated by the copper before the connexion between the Galvanic trough could be formed.

I have here, Sir, endeavoured to give you as clear and as full a description of the Pile of Volta, the

mode of constructing and adapting it to use, as was consistent with the design of this essay ;—while engaged in other professional duties and pursuits, it can scarcely be expected that these outlines should be free from a variety of errors ; the whole, however, is the result of some observation and experience. To diffuse a more general knowledge of a science so interesting in itself, and so capable of being applied to many useful purposes, has been my principal object, if it has led me imperceptibly into a fuller investigation of the subject than I originally intended, your candour I hope will make allowance for the intention, and your judgment will correct its imperfections.

You, my Dear Sir, have called forth these observations, such as they are, accept them as a trifling proof of the respect and esteem with which I subscribe myself,

Your

Very sincere Friend,

W. M.



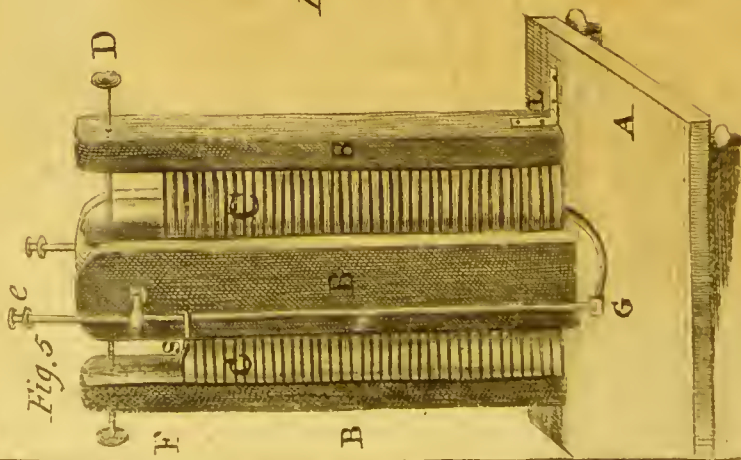


Fig. 5

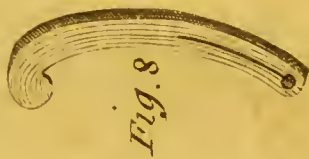


Fig. 8

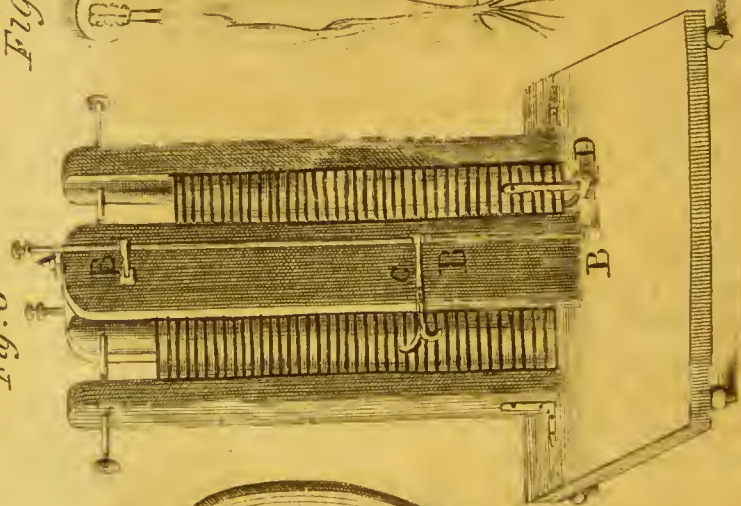


Fig. 6



Fig. 2

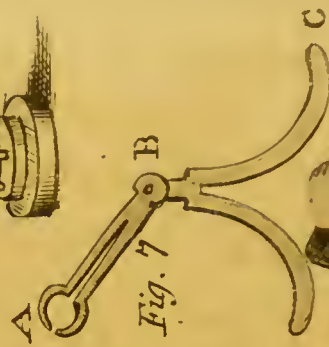


Fig. 7



Fig. 1.



Fig. 9.



Fig. 10.



Fig. 11.



Fig. 3.

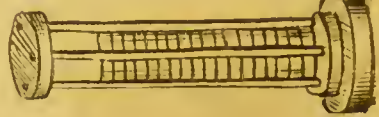


Fig. 4

EXPLANATION OF PLATE Ist.

Fig. 1. Represents the lower extremities of a prepared Frog *A* fixed on a rod of zinc *B* when a communication is made with a silver probe between the legs of the Frog and the rod *B* the muscles are thrown into spasmodic action.

Fig. 2. is shewn a Frog prepared in the same manner, with its feet placed on the silver plate *S* while the sciatic-nerve attached to part of the vertebre is placed on a plate of zinc *Z* when a communication is made between these two plates, with the conductor *R* the Frog is instantly thrown into convulsive action.

Fig. 3. Represents a Galvanic combination produced by two dissimilar fluids and one metal. *B* is a glass dish filled with water, into which is placed a small silver cup *S* filled with dilute nitrous acid—in order to produce the same spasmodic action in the muscles of the Frog, as in the above experiments, nothing more is necessary than to complete the circle with the animal as is represented at *C*.

Fig. 4 Represents the Galvanic Pile as originally contrived by Volta, supported in a frame, and excited into action by disks of wet cloth interspersed between the plates.

Fig. 5. Represents the back view of Fitzgerald's improvement on the Pile of Volta. *A* is a stand on which the Pile is supported, *B B B* are three pillars made of hard wood, and lined with a coat of cement, they serve to support the plates *C C* in their proper situation, and in order to erect the plates on each other, the two side pillars turn down by the hinge *L*. When the Pile is constructed, these side pillars are screwed tight by a rod which passes through the centre pillar, and is sufficiently tightened by a button *D* which screws on this rod. The communication is made between each Pile by the brass rod *E* which is screwed into the conducting wire of the lower plate *G* and establishes the communication with the second pile by a moveable conductor *S*.

Fig 6. Represents the front of the same Apparatus, the two tier of plates or cups being connected at the back as before described in *Fig. 5* *B B* is a brass rod, insulated at each end by passing through Glass Tubes cemented to the centre column *A*. When the Piles are constructed and the side pillars turned up and screwed tight, the charge is taken with great precision by touching the rod *B* and the brass pin *D* which is connected with the lower plate of the pile.—The conductor *C* slides on the rod *B*, and serves to regulate the strength of the shock by placing the point of it between any given number of plates on either side of the pile.

Fig. 7. Represents this moveable conductor separate, A, the groove which admits it to slide on the brass rod B Fig. 6. and in order to change it to either side of the Pile so as to include any given number of plates, it moves with a hinge B. The points C are shaped so as to pass easily between each plate or cup, so as to take the shock between the pin D Fig. 6. and any number required.

Fig. 8. is the brass conductor which moves on the rod E G Fig. 5. and serves to establish the communication at S. between the two piles C C.

Figures 9 10 11 Represent the zinc and copper plates which are used in the formation of the Pile, the construction of them is exclusively the contrivance of Fitzgerald, and in this invention the principal merit of his instrument consists.

Fig. 9. represents a circular plate of Copper A turned in a lathe and scooped, so as to represent in some measure the cover of a pill-box.—To the bottom of this cup is soldered a plate of zinc, about the thickness of a penny piece, but not so large as the copper cup.

Fig. 10. Represents the same sort of copper cup as at A Fig. 9, but without a plate of zinc attached to it. This is the first cup used in the formation of the Pile, and is farther represented at D Fig. 6. When therefore it is wished to form the Pile, nothing more is necessary than to fill this cup with a dilute acid nearly to the top, and then to place on it the cup Fig. 9. with the plate of zinc B. soldered to it: by this means the zinc and copper are both in contact with the fluid, and the two copper plates are prevented from touching each other by small bits of whale-bone cemented to each plate; this simple contrivance therefore, precludes the necessity of using disks of wet cloth between the plates, and by exposing each metal to a fluid contained in separate cells, it has all the advantages of Cruickshank's trough, without deviating materially from the construction of the Pile, while at the same time it enables us to separate and clean them at pleasure. Thus, in forming a pile to any extent, nothing more is necessary than to construct any number of cups of the form Fig. 9. of any dimensions and by filling each cell with a fluid, and piling them as described over each other, a very powerful battery may be formed capable of continuing in action for several hours.

Fig. 11. Represents the first cup of the second Pile, as shewn at G. Fig. 5. when filled with a fluid, such another cup as is described in Fig. 9. A is placed on it with its corresponding plate of zinc B soldered to it; thus, by adding in succession a sufficient number of these cups, the second Pile is formed in the same manner as the first.



Fig III

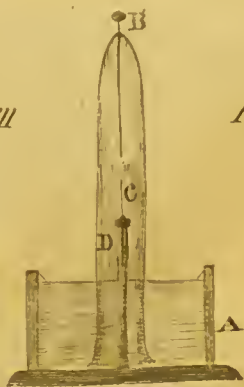


Fig II

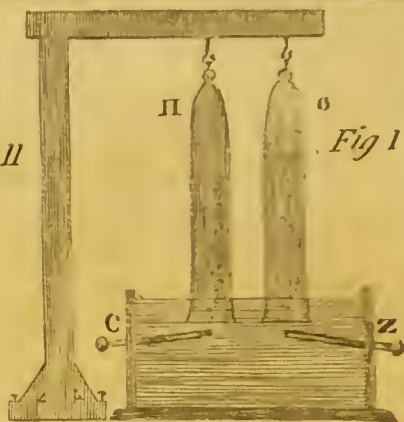


Fig I

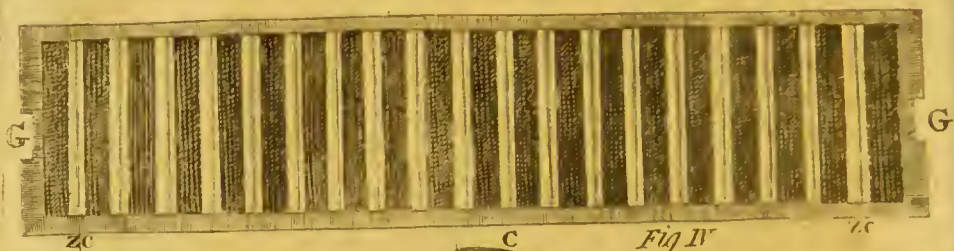
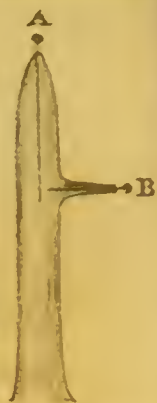


Fig IV

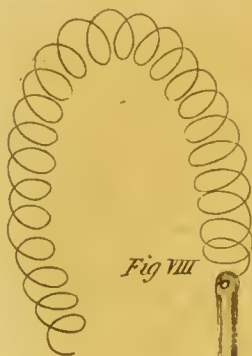


Fig VIII

Fig III



Fig VI

Fig V



EXPLANATION OF PLATE 2^d.

Fig. 1. Represents a glass tube for receiving oxygen and hydrogen gases; this tube, when filled with water, is placed on the dish A. *Fig. 3.* When these gases have filled the tube as far as the lower point of the wire A. *Fig. 1.* the electric spark passed between the wire A. B. will explode them and form water.

Fig. 2. Represents two glass tubes suspended over two wires Z & C to receive the oxygen and hydrogen separately; the wire Z. is connected with the zinc side of the trough, and C. with the copper side; thus the tube O. receives oxygen, and the tube H. hydrogen.

Fig. 3. Represents a glass tube with a gold wire B. hermetically sealed in it; this tube is filled with water and inverted over the wire C. which is screwed into the dish A. This wire can be changed, by slipping it out of the groove D. where it is held by a ring. By this means experiments on different metals, as well as on different metallic solutions may be easily tried.

Fig. 4. Represents the Galvanic trough containing plates of copper and zinc; the dark shades represent the cells for holding the fluid; Z. and C. represent the zinc and copper plates soldered together. G. G. represents grooves at each end of the trough into which the two conductors, *Fig. 6. & 7.* slide, so as to communicate with the cell at each end.

Fig. 5. Represents a brass discharging rod, one of which is to be held in each hand to receive the shock; A. represents the handle, which is much thicker than the point B. in order to expose a greater surface to the hand.

Fig. 6, & 7. Brass conductors, the ends B. B. slide in the grooves G. of the Galvanic trough; the point C. of *Fig. 6.* is turned down into the dish A. *Fig. 3.* while the straight point C. of *Fig. 7.* is placed on the button B. of *Fig. 3.* the circle between the wires C. & B. is then completed, and gases arise according to the side of the pile to which the conductors are attached; and in order that the conductors should be adapted to any part of the trough, they move on the joints D. in a circular direction.

Fig. 8. Represents a brass rod, partly covered with resin or wax, for medical purposes, one of these should be connected by the spiral wire to each end of the conductors, *Fig. 6. & 7.* which have small holes perforated at the round points to admit them; these rods are held by the resinous part, and the points A. should be applied to that part of the body through which it is wished to pass the Galvanic current.

THE HISTORY OF THE

REIGN OF

CHARLES THE FIRST

BY

JOHN BURNET

OF THE UNIVERSITY OF OXFORD

IN TWO VOLUMES

LONDON

Printed by J. Streater, at the Sign of the Gun, in St. Dunstons Church-yard, near the North Gate

1679